What causes seasonal variations in meridional overturning and heat transport of the Indian Ocean?

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The dynamics of a GCM of the Indian Ocean is fitted to monthly averaged climatological temperatures, salinities, and surface fluxes using the adjoint method. Interannual variability is minimized by penalizing the temporal drift from one seasonal cycle to another during a ilwc)-yea] integration. Monthly properties in sponge layers near the southern boundary, the Indonesian Throughflow channel, the Red Sea, and the Persian Gulf are estimated as part of the optimization procedure. The resultant meridional overturning and heat transport display large seasonal variations, with maximum amplitudes near 10°S of up to 18×10^{6} m^3/s and 2 x 10^{15} W, respectively. To explain the dynamical causes for these variations, the meridional transport stream function is decomposed into four components: The first component describes the external mode, which is governed by the generalized time-dependent Sverdrup relation and influences the meridional overturning in the presence of zonally non-uniform topography. The second component is the Ekman flow minus its projection onto the external mode. The third component represents thermal wind shear. The fourth component consists of ageostrophic flow associated with friction and nonlinear effects. Due to monsoon reversal over the Northern Indian Ocean and the change of easterlies over the subtropical Southern Indian Ocean, the Ekman component causes dominant seasonal variations in meridional overturning and heat transport. The external mode causes moderate seasonal variations as a result of the Samoli Current reversal. There is moderate and partially compensating seasonal variability in the thermal wind and ageostrophic contribution. From our model-data synthesis, we conclude that direct wind forcing is the major mechanism which drives the seasonal cycle in meridional overturning and heat transport of the Indian Ocean.